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TITLE : PARKING SUPPORT DEVICE

[Detailed description of the invention]

[Problems to be solved by the invention]

[0006] This invention has been accomplished under such circumstances as set out hereinabove and has for its object the provision of a parking support device in which a possible arrival range for backward moving vehicle is displayed being superimposed on a monitor image of a parking space so that the suitability of a backward movement starting position can be confirmed by comparing the displayed parking space and the displayed possible arrival range.

[Embodiments of the invention]

[0029] (Edge-approach operation) Display for an edge-approach operation is made, as shown in FIG. 9, in which the outermost extending lines (parallel to a central axis of the vehicle) L_{BL} and L_{BR} obtained by perpendicularly projecting the outermost lines W_{BL} and W_{BR} of a vehicle to a ground surface and extending the lines W_{BL} and W_{BR} forward and backward, are displayed on a screen, being superimposed. In this case, outer extension lines of tires may be displayed in place of the outermost extending lines L_{BL} and L_{BR}. These outer extension lines are not required to strictly accord with the outermost of the vehicle or the outermost of the tires, and the lines each may have a margin of about 20cm from the outermost side. Alternatively, as shown in FIG. 10, the outermost prediction loci of a vehicle or prediction loci L_{BS} and L_{TS} of the outer lines of tires may be displayed as shown in (1) and

(2) of FIG. 10 in accordance with steering rudder angle. How the prediction loci are displayed will be described in detail in the section of "Obstacle avoiding operation".

[0030] The subsequent display is made when a driver selects "edge approach" through a selector SW shown in FIG. 2. A processing flow that follows this selection is shown in FIG. 11. The edge-approach operation should not be performed in high speed driving but should be performed only in low speed driving. This is because the edge-approach operation in high-speed driving is dangerous, and because there is a probability that image information causes a driver's attention to be scattered. When the driver intends to stop the vehicle as close as possible to a gutter located on a left side of a road in forward running, the driver is supposed to select "left approach" through the selector SW. This selection is judged as having done at step SA-1. In this state, when the vehicle speed becomes lower than a preset speed, forward running is judged as having been established at step SA-2, and a processed image P_{FL} is displayed at step SA-4. Then, the driver is supposed to operate the vehicle so that its leftmost outer line L_{BL} is superimposed on the gutter image on the screen, thereby easily completing edge approach. Subsequently, when a shift lever is put into a "P" range position, judgment is made at step SA-11 responsive thereto, that there has been an input through a position SW (switch) 23 to release the selector SW at step SA-12 for completion of the edge-approach support. The selector SW is supposed to be released on such other occasions that a vehicle has been stopped for more than a predetermined period with the shift lever being placed at an "N" range position, or a vehicle has been stopped for more than a predetermined period with a brake SW (switch) on, or the engine has been stopped. When a vehicle is required to go backward depending on circumstances during the edge approach, the shift lever is put into an "R" range position. In this case, in response to the judgment at step SA-2 based on the input through the position SW 23, an image of P_{RL} is changed, at step SA-5, to a backward movement support image. In particular, in case of backward movement, since the front left corner section of a vehicle sways right and left, it is effective to display the images P_{FL} and P_{RL} simultaneously, as shown upper right of FIG. 11. The explanation, so far, has been premised on a typical front-wheel steering mechanism. In case of a

four-wheel steering mechanism as adopted in some vehicles, it is effective to display the two images simultaneously in forward movement, in addition to backward movement, as shown upper right of FIG. 11.

[0031] On the other hand, when a driver desires to have the vehicle approached right side of a road depending on circumstances, processes are taken by selecting "right approach" through the selector SW for establishment of the right-approach judgment at step SA-1. Then, depending on forward movement or backward movement as judged at step SA-3, an image is displayed at either step SA-6 or step SA-7. When the instant vehicle passes other vehicle in a narrow road or when the instant vehicle passes through a road narrowed by obstacles or the like, upon selection of a "center edge approach" through the selector SW, judgment is made as to forward movement or backward movement at steps SA-1 and SA-8, and in response to which left and right images for either the forward movement or the backward movement are displayed at either step SA-9 or step SA-10, thereby providing driving support as required by the driving operation. It should be noted that, in FIG. 11, images are shown with partial omissions for the purpose of simplification, with the exception of the left-approach image. Actual displays include an image as shown by the left-approach image.

[0032] (Obstacle avoiding operation) In obstacle avoiding operation, as shown in FIG. 12 (an example for avoiding a vehicle which is parked in front of the instant vehicle, using an image of a front left corner), the prediction locus L_{BS} of the left front corner section is displayed in accordance with the steering rudder angle. The prediction locus L_{BSF} in forward movement and the prediction locus L_{BSR} in backward movement are distinguishably displayed. The prediction locus L_{BS} displayed in this case is not the assumption line on a ground surface as in the edge-approach operation but is a line based on an outermost left corner. The reason for this, as shown in FIG. 12, is to avoid an obstacle N' and also to make the display easy to understand for a driver. However, in the case of this image, when the outside of a vehicle is dark or when the color of the instant vehicle body is dark, or, contrarily, when the shadows of the instant vehicle body or other objects are projected on a road surface through sunlight or illumination

lamps, it is sometimes difficult to distinguish the profile of the instant vehicle body on the screen. To cope with this, as shown in FIG. 12, a profile (the outermost edge line) L_{PF} of the instant vehicle body is displayed being superimposed on the outermost edge of the instant vehicle body 90', by which the driver is enabled to very easily distinguish the instant vehicle. This way of display is applicable to other functions.

[0033] Display in this operation should be made only in low speed driving, according to the flow chart shown in FIG. 13, as in the case of edge-approach operation. A driver is supposed to operate the selector SW (for example, "front left") shown in FIG. 2, and responsive to which, judgment is made at step SB-1 to display an image (for example, FIG. 12) of the corresponding corner at step SB-2. At the same time, a steering rudder angle and prediction loci L_{BSF} and L_{BSR} of a vehicle-body corner in forward movement or backward movement are displayed on the basis of the input from the steering rudder angle sensor 26. This display is terminated, when all the distances detected by distance sensors 28 are judged to exceed a reference value, with the release of all corner switches in the selector SW at step SB-4. When the selector SW is not operated, the procedure proceeds to B' by the judgment at step SB-1. When one or more distances detected by the distance sensors 28 are judged, at step SB-5, to be lower than a reference value and when the distances are judged, at step SB-6, as being shortened, the image of the corresponding corner is displayed at step SB-7, and warning is given to the driver at step SB-8. An example of the display in this case is shown in FIG. 14, wherein the front left corner section is taken for an example. In FIG. 14, the front left corner section of a graphic MI of the instant vehicle is displayed in warning color or being flickered, and the image P_{FL} of the front left corner section is displayed at the corresponding position on the screen. In addition to the visual warning, audible warning may be given by voice and sound. When there are a plurality of corners, a plurality of images or warning indications should be added to the corresponding positions on the screen shown in FIG. 14.

[0034] (Parking operation) Description is now provided with reference to FIG. 15 and taking a case of backward parking as an example which is said to be the most difficult technique in parking operations. In this operation, a

target parking space is checked at a position ①, and a vehicle is moved forward to a parking operation starting position ②, and the vehicle is stopped in a parking position ④ by way of a position ③ by backward movement. The key to efficient parking operation is how the parking operation starting position is determined, and what the driver targets at when passing the position ③. In principle, when a target parking space U is within (upper portion in the FIG. 15) a minimum turning radius R of the vehicle at the position ②, the vehicle cannot be brought to a proper parking position by one turning operation of the steering wheel, but by more numbers of turning operations. As a general rule, since a minimum turning radius of an ordinary passenger vehicle is around 5m, a position of a vehicle L-2 (which should be an assumed position when there is no vehicle L-2), *i.e.*, a second vehicle from the instant vehicle is targeted. Most drivers determine the position ② depending on their experience and feeling, but nevertheless, it is difficult to park the vehicle without giving repeated turning operations of a steering wheel.

[0035] In the parking operation, processes are taken by superimposing, on images taken by the cameras 21, a possible parking range defined by either the left or the right side of the parking space including left and right margin spaces required for backward parking at the maximum rudder angle, whichever is nearer to the instant vehicle (*i.e.* left side of the vehicle in case of backward parking toward left rear, and right side of the vehicle in case of backward parking toward right rear). Specific explanation of the backward parking in a left rear direction is provided hereinafter. At the parking operation starting position ②, as shown in FIG. 16, a possible parking range Z_I is displayed. This possible parking range Z_I is set as an area that includes margins on the left and the right sides of the vehicle when the vehicle is parked in the target parking space U shown in FIG. 15 at a posture ④ which is right angle to the posture at the parking operation starting position ② from where the vehicle is started backward with the steering wheel being turned at a maximum angle. The lateral boundary shown in FIG. 16 is the left side limitation (when the concept of this limitation is indicated by tracing back from the actually displayed position to the position where the backward movement is started, the boundary results in as shown by an imaginary line in FIG. 16). The longitudinal

boundary shows the limitation that includes a retainable predetermined margin in front of a vehicle at the posture ④. Specifically, as shown in FIG. 17, the possible parking range Z_I is determined based on white lines W'_P in an imaged target parking space U' (the imaged space U' is determined so as to include, *in se*, certain spaces on the front, rear, right and left sides of a vehicle in a parked position). The range Z_I is determined based on experiments or calculations from vehicle items, the design criteria of the parking space and the like. In an actual operation, as shown in FIG. 16, if the imaged target parking space U' is large enough to include the possible parking range Z_I as seen at the parking operation starting position ②, the driver can operate the vehicle without difficulty. As shown in FIG. 17, if the lateral and longitudinal boundaries approximately match the lateral and longitudinal lines of the W'_P lines, a vehicle can be parked by narrow margins at a predetermined position without being slanted, by turning the steering wheel at a maximum angle. Accordingly, if the possible parking range Z_I is offset below from the position shown in FIG. 17, it means that the parking operation starting position ② is too much backward. Also, if the possible parking range Z_I is offset to the left, it means that the parking operation starting position ② is too leftward.

[0036] When a vehicle moves from the parking operation starting position ② to the parking position ④ through the intermediate position ③, the images of the rear right and the rear left are simultaneously displayed on a single screen, as shown in FIG. 18. Further, as shown in FIG. 18, the left rear image P_{RL} is arranged on the left side and the right rear image P_{RR} is arranged on the right side, with the outermost extension lines L_{BL} and L_{BR} being displayed, respectively, in the same manner as in the images P_{FR} and P_{RR} shown in FIG. 9. These lines may be indicated in the form of a prediction locus L_{BSR} in accordance with a steering rudder angle. The distance between the left and right images, which is to be set so as to be real to the driver, can be determined through a test evaluation. The images shown in FIG. 18 are independently laid out, each being supplied with a wide angle lens so as to have a bird's eye view including an instant vehicle corner and an infinite distance, so that a region shown by R in FIG. 1 may be superimposed thereon. In this way, a simulated composite image of the rear can be constituted by an extremely simple process of removing a gap

between the two images or cutting the inner sides of the images for juxtaposition. An example is shown in FIG. 19.

[0037] As shown in FIG. 18, the images can be rendered easily understandable by displaying a target parking frame reference line W_I. This target parking frame reference line W_I which is superimposed on the images depicts a shape of a parked space in case the vehicle is orderly parked in a standard parking space. That is, as shown in FIG. 19, the instant vehicle is operated so that the target parking frame reference line W_I matches the target parking space U in the parking operation, whereby the driver can clearly grasp the position of the instant vehicle in terms of margins on the right and left sides, and a position in a forward or backward direction and a slant with respect to the target parking space U upon completion of the parking operation. This enables an inexperienced driver to park a vehicle in good order. A driver is supposed to operate a vehicle so that the target parking frame reference line W_I matches the imaged target parking space U' on the screen. Safety can be much ensured if a warning is given and additionally displayed as in the obstacle avoiding operation of B by the operation of the obstacle sensors 28 at the front, rear, left and right, and the cameras 21 shown in FIG. 3. This parking operation support technique is applicable to longitudinal parking or forward parking, the explanation of which is omitted.

[0038] Display in this case should be made following the flow chart shown in FIG. 20. Also, in the same manner as in the two operations set out above, support should be performed only at a low vehicle speed. This processing flow is started when a driver selects a parking SW shown in FIG. 4. In left backward parking shown in FIG. 16, a driver is supposed to select SWP_L, and in right backward parking, a driver is supposed to select SWP_R. The following is an explanation on left backward parking based on the judgment at step SC-1 responsive to the selection. When the information inputted from the position SW 23, which serves as an input device, is judged, at step SC-2, as moving forward, the possible parking range Z_I explained referring to FIG. 18 is superimposed on the left rear image P_{RL}. In this state, when the driver operates the vehicle so as to bring the imaged target parking space U' into the possible parking range Z_I, the driver can stop the vehicle at

an appropriate parking operation starting position ② as explained in FIG. 16. When the driver puts the shift lever into a backward movement position, confirming this state, to input the backward moving information through the position SW 23, the two rear images P_{RL} and P_{RR} are simultaneously displayed at step SC-5, and the prediction locus L_{BSR} which is in accordance with the steering rudder angle is superimposed at a corner of each image. Referring to this, the driver operates the vehicle to bring the imaged target parking space U' into the possible parking range Z_I. This processing is shown in FIG. 19. ②, ③ and ④ in FIG. 19 are represented in FIG. 16. This processing flow is terminated by the switch release at step SC-9 on the basis of the shift judgment in respect of a parking range at step SC-8.

[0039] (Blind corner) Display for this operation is made as shown in FIG. 21 (an example of the image P_{FL} including a blind section in a front left direction). Specifically, an image of the blind section is displayed on a screen, over which a scale of a standard distance from the instant vehicle on the ground level is displayed as a distance line L_K. The blind sections at the front right, the rear right and the rear left are displayed in the same manner. In this case, as shown in images (1) or (2) in FIG. 22, the right and the left images may be simultaneously displayed in forward movement or backward movement. Considering symmetry in such a simultaneous display, the angles of the cameras may be slightly changed. Specifically, when the optical axes X of the cameras 21 are concerned, one of the right and left corner cameras 21 (for example, C_{FL}) of the vehicle which is set up at a certain angle in a perpendicular plane which includes a straight line connecting the driver and the camera 21, may be arranged so as to be plane-symmetric to the other corner camera 21 (for example, C_{FR}) in respect of a central axis of the vehicle. It would be more understandable if the graphic M_I of the instant vehicle is superimposed on the longitudinal centerline on the screen so as to confront the right and left images of the front or the rear.

[0040] Display in this case should follow the flow chart shown in FIG. 22. This flow chart, as explained in the main flow chart, should be followed only in low speed driving. When a driver steps on a brake, on conditions where a

blind SW (front left, front right, rear left and rear right) shown in FIG. 2 is selected according to the judgment at step SD-1 responsive to a brake switch 24, the one side image shown in FIG. 21, or the image (1) or (2) in FIG. 22 is displayed depending on forward or backward movement as judged at step SD-2 responsive to the input through the position SW 23. In case of the image (1), the front left image P_{FL} and the front right image P_{FR} are brought to the positions that confront corresponding portions of the graphic M_I of the instant vehicle, followed by superimposing the distance lines L_K as shown in FIG. 22. These distance lines L_K are also indicative of the driver's gaze direction, providing good gaze points to the driver.

[0041] (Checking rear dead angle) A processing flow for checking a rear dead angle is shown in FIG. 23. Display for this checking is made on conditions that the instant vehicle is running at more than a preset speed on a two-lane section, as judged at step SE-1 based on navigation information, in an area not close to an intersection, as judged at step SE-2, that winker is judged as having been operated at step SE-3, and thus that overtaking or pulling in is judged as having been done. The subject rear image is then displayed at step SE-4 or step SE-5. Referring to the displayed image, the driver can operate the vehicle. The information including the number of lanes on a road where the instant vehicle is running and which lane the instant vehicle is running, is readily available by using white-line detecting technology which will be described hereinafter. This information may also be readily available by using signals from optical beacons which are set up in highways. Simple utilization of this information in combination with winker operation readily enables judgment on overtaking or pulling in. When the information is combined with navigation information, precision in the information is naturally enhanced.

[0042] (Checking white line) A flow chart for checking a white line is shown in FIG. 24. Display in this case is made on conditions that the vehicle is judged to be running at night in rain at more than a certain speed by judging headlights as having been lit, at step SF-1, and by judging a wiper as having been operated, at step SF-2, and that a side lamp is lit, at step SF-4, to illuminate the road in a forward direction from the left side. Upon satisfaction of these conditions, an image shown in FIG. 24 is displayed at

step SF-5. When the night and rain judgments are negative in the above processing flow, the processing is switched to the flow for "Checking rear dead angle" described hereinbefore. Even when both of the judgments are affirmative, if a winker is operated, then, the rear dead angle image is immediately displayed, skipping the judgment conditions in the flow for "Checking rear dead angle". Lighting a side lamp is not an essential matter. This is because the directions of headlights of a coming vehicle are considerably different from the directions of the optical axes of the left and the right cameras C_{RL} and C_{FR} of the instant vehicle, and thus when the light of the coming vehicle is regularly reflected from a water surface, no entry is made to CCDs of the cameras, causing no dazzling to the driver, and also because the light reflected from a white line is irregular and thus can be caught by the CCDs. In this way, white lines can be well detected covering the range from the sides of the instant vehicle to a little ahead of the instant vehicle, making use of the illumination of a coming vehicle, a following vehicle, an adjacent vehicle or the instant vehicle. The side lamp is lit just to obtain a better sight.

[0043] As shown in FIG. 24, images of the camera C_{FL} at the front left corner section and the camera C_{FR} at the front right corner section are displayed on the same screen. It is desirable that the display is made so that the relative relationship between the right and left white lines W'_{LL} and W'_{LR} be similar to an image taken by one camera. Further, when the color of the instant vehicle is dark, it is difficult to distinguish the instant vehicle in the image. Therefore, it is also desirable that the profile line L_{PF} of the instant vehicle is superimposed on the image so that the instant vehicle can be easily distinguished from the road surface.

[0044] (Detecting a white line) The driving support system of the embodiment is also applicable to the detection of a white line. Since the specific techniques for detecting white lines are well known, explanation thereon is omitted. In majority of such techniques, cameras are installed in the vicinity of the front glass inside a vehicle. Contrarily, in the system of the present invention, white lines can be detected by using two cameras for detecting dead angle at the front right and the front left corner sections. In this way, the present invention provides such advantages that: in detecting

a lateral white line near the instant vehicle making use of the wide lateral view, a characteristic of the driving support system of the invention, accuracy is ensured in the relative positional relationship between the instant vehicle and the white line; as described hereinbefore in the indication of a white line, white lines are detectable at night in rain or mist; and costs can be reduced because detection of white lines can be conducted by sharing a function which serves for other purposes.